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INSECTS INJURIOUS TO STORED GRAINS AND THEIR GROUND PRODUCTS

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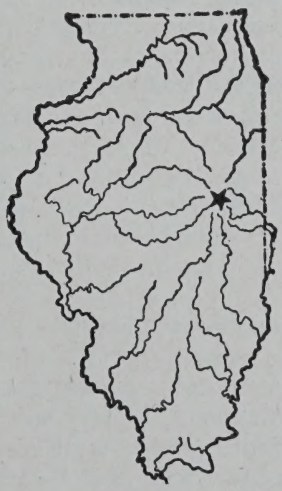

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Contents of Bulletin No. 156

INSECTS INJURIOUS TO STORED GRAINS AND THEIR GROUND PRODUCTS

By A. A. GIRAULT, assistant to state entomologist

It is well known that many kinds of insects live in wheat and other grains and in meal and flour, either accompanying the grain to the granary from the field, or going to it after it is stored. Many, indeed, go with it from the producer to the customer—thru cribs, elevators, mills, and warehouses, to the retail store, and thence to our homes. Insects of these habits are particularly hardy, and many are so far omnivorous that they may live and multiply on food which seems to us to contain no nourishment. All are either beetles or their larvæ, or the larvæ of moths. The latter are of fewer kinds but of greater capacity for mischief than the former. At any particular time and place, half a dozen to a dozen of these insects may be present, working in various ways, some of them, indeed, not directly injurious but feeding on chaff or other granary debris, and obnoxious merely by their presence. Of the others, one or more may be injuring individual kernels of grain in a way to make them unfit for food and to prevent their growing if sown; or one may be webbing together flour and meal in mills, making them useless for food, and also clogging some parts of the machinery by webbing together masses of flour. Further harm may be done by causing fermentation in the stored grain. The percentage of actual injury may not be large for the whole mass infested, but the mere presence of considerable numbers of these insects reduces the value of the grain or flour, and may interfere seriously with its sale.

Over fifty species live habitually or occasionally in stored cereals and cereal products in the United States, but only about ten of these are of the first importance. Seventeen are habitual grain eaters, but the food of the others is comparatively miscellaneous, including granary rubbish, decomposing substances, cloth materials, and dried animal matter. Those which are regarded as of prime importance are the Angoumois grain moth, the Mediterranean flour-moth, the Indian meal moth, the meal snout-moth, the confused flour-beetle, the granary weevil, the rice-weevil, the saw-toothed

grain-weevil, and the yellow meal-worm. Of the eight remaining habitual grain eaters, about two thirds are closely related to one or more of the preceding, but specifically distinct and less numerous.

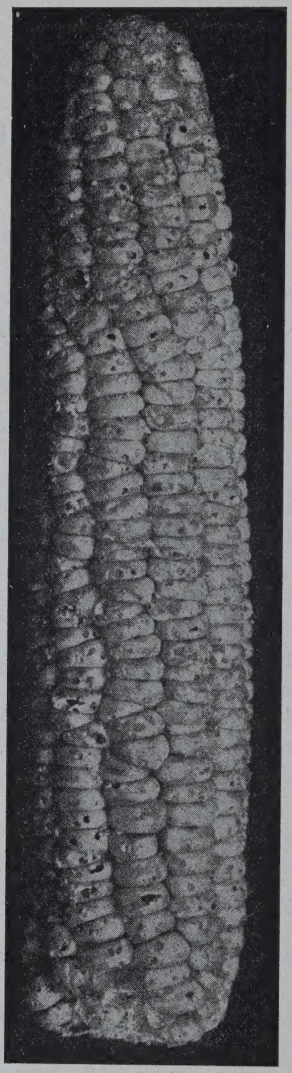

Fig. 1. Ear of corn injured by Angoumois Grain Moth, *Sitotroga cerealella.*

Among the forty species which are classed as miscellaneous in their food habits, some, such as the carpet-beetles, are usually household insects, and others infest museums, while a large number simply enter the granary, not merely because it contains grain, but

for shelter and for other food, including such substances as the dirt in the cracks of the floors, bits of broken grain, dead insects, insect castings, molds, cobwebs, and cloth; or they may feed occasionally on grain alone. Many of these insects are introduced species, of cosmopolitan range, and are scattered abroad in shipments of stored grain and other products.

GRANARY MOTHS

THE ANGOUMOIS GRAIN MOTH

(*Sitotroga cerealella* Ol.)

A characteristic example of the work of this insect is an ear of corn peppered with small round holes, often two or three to a single kernel (Fig. 1). These are produced by a caterpillar which has eaten out the embryo and the other soft parts of the seed and has then cut through the top of the grain a small round hole which it has covered with a web. In the cavity within the kernel it changes to the moth, and then, breaking thru the delicate silk cover closing its burrow, it makes its way to freedom and takes flight.

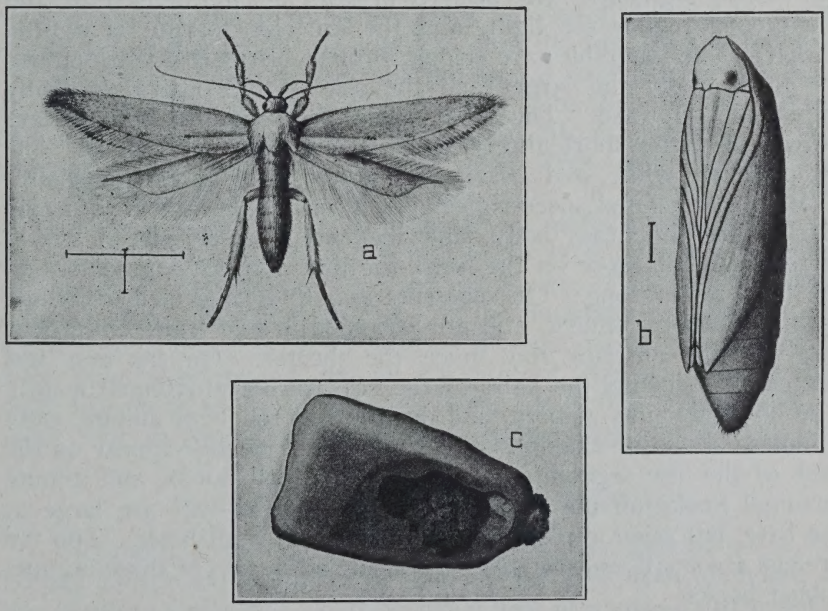

Fig. 2. Angoumois Grain Moth, *Sitotroga cerealella: a*, imago (×5); *b*, pupa (×13); *c*, grain of corn with a portion of surface removed to show injury (×3½).

DESCRIPTION

This insect belongs to the *Lepidoptera,* or family of moths, the young of which are called caterpillars. This species is commonly known to grain men as the fly-weevil—a very inappropriate name because it is not in any sense a fly.

The eggs laid by the female on the kernel are at first milky white, but soon turn to a pale reddish. They are elongate, slightly bottle-shaped, about a fortieth of an inch long, with a roughened surface which, when magnified, is seen to be marked with minute rectangles in regular rows, giving them a resemblance to ears of corn.

The recently hatched caterpillar eats its way into the lower end of the grain, making a barely visible round hole, which is the less noticeable because it is covered over with silk. The caterpillar begins to feed at once on the starchy material surrounding the embryo, and destroys the latter by the time it has itself become full-grown. (Fig. 2, *c.*) It is then about a fifth of an inch long, whitish, with a brownish head. A more complete description follows.

When first hatched the larva is no thicker than a hair, but when full-grown it is rather robust and gradually tapers backwards from the second segment. The head is brown, its lateral margins and the ocellar region are light, and the anterior margin is a little darker. The mandibles are strong, brown, bisetose, quadridentate, the lower tooth the larger and the size of the others gradually diminishing upward. The other mouth-parts and the antennæ are brown, the latter short, three-jointed, and ending in a bristle. The six ocelli are white, and arranged in the form of an elongate letter C, with the inclosed space varying from very dark brown to nearly black. On the head, body, and legs are sparsely-placed white, setaceous hairs, those on the head, the first and last segments, and the legs, rather long. On segments two to twelve inclusive these hairs are less prominent, and are arranged in two transverse rows, those of the anterior row much the shorter. On the first and thirteenth segments the hairs of the two rows are of equal length. The body is white, smooth, and densely covered with minute, erect spinules. In some examples traces of brown patches appear on the back of the first segment. The spiracles, dorsal hooks, and minute terminal hooks on the prolegs are brown. The legs are large at the base, but taper rapidly, each ending in a small hook. The ten prolegs are small and wartlike, and each end in two or three minute, robust hooks.

The pupa (Fig. 2, *b*) is about a fifth of an inch long, brownish, pointed ovate, with the adult appendages outlined thru the crust along its under surface. The wing-pads nearly reach the tip of the abdomen. The head end is obtuse; the posterior end

more acute, and surrounded by a ring of sparse setæ. The head, thorax, and wing-pads are dark, the abdomen lighter brown. Eyes in mature pupæ black, and distinctly visible. On the abdomen are several rows of setæ, as follows: a double row on the side, above the spiracles, placed in pairs; a single row just below the spiracles and close to them; another double row on each side of the middle line of the body, the outer hair of each pair being on the posterior part, and the inner one on the anterior part of the segment. There are two long, slender, conspicuous bristles on the segment immediately behind the head.

The adult (Fig. 2, *a*), familiar to most elevator men, is a delicately built, small moth, with a quick wavering flight, which may be seen in infested rooms resting on bags of grain, walls, windows, or the like. It is about three eighths of an inch long, and grayish clay-yellow when at rest, but with hind wings dark grayish or neutral gray, and bordered with close, exceedingly delicate, silvery fringes. Each fore wing bears a black dot between its base and its middle.

LIFE HISTORY

When bred indoors the generations of this insect become confused, all stages being represented at once; but in the field there are two generations, which become adult in May or June and in August respectively. Where ear corn is infested in the crib the eggs are placed in the groove of the kernel on the ear, usually beneath the membrane which ensheathes the tip of each kernel. Wheat may become infested by the second brood of moths either thru eggs laid in the field on the grain in the head or else after storage in the granary, and a generation may develop from these eggs within five or six weeks. If an infestation begins in the field and the infested grain is carried to the granary, the moths come to maturity and continue to breed in the stored grain as long as the weather will permit; and the same is true, of course, if the grain is first infested after it has been stored. If the temperature of the storehouse is kept up by artificial heat, as in some warehouses, development may be continued thruout the winter; otherwise the female may deposit from sixty to ninety eggs, which hatch, as a rule, in from four to ten days, according to temperature.

DISTRIBUTION, INJURIES, AND ENEMIES

This moth, first noticed in France, is widely distributed in the United States and Europe. In this country it is most abundant in the southern states and where artificial heat promotes its multiplication in the northern granary.

Wheat may be as badly infested by this moth as corn, the heart of each grain being eaten out. Other cereals are injured less com-

monly, and cow-peas are sometimes infested by it. While the caterpillar is still young, infested kernels can not be distinguished except, perhaps, by their light weight. Later, however, a visible hole is made in the grain after the caterpillar is full-grown.

The larvæ of this species are infested by at least one parasite, and also by a minute, predaceous mite *(Pediculoides ventricosus* Newp.). This latter sometimes breeds in infested grain to an extent to become enormously abundant. By its infinitesimal bites it irritates the human skin, causing a rashlike and sometimes rather severe eruption, very annoying to harvest hands, grain-house employees, and others having to do with the handling of grain.

This grain moth may be most readily destroyed by fumigation with carbon bisulfid as described on another page.

THE MEDITERRANEAN FLOUR-MOTH

(Ephestia kuehniella Zell.*)*

When wheat flour in mills is webbed together in more or less irregular, matted masses (Fig. 3), very likely to cause trouble by clogging the mill machinery, the presence of the Mediterranean flour-moth is to be inferred. The adult of this insect is a small moth or miller, harmless in that stage, however, and injurious only as a larva. Its caterpillars make tubes of silk in which they live, covering them with flour upon which they feed. When full-grown they discard this tube and wander about in search of suitable places in which to pupate, spinning silk as they crawl, thus webbing the flour together. Preparatory to pupation a cocoon is also spun of silk matted with flour, which adds to the nuisance created by their presence.

DESCRIPTION

The egg of this insect is a little more than a sixtieth of an inch in length, elongate-oval, white and almost smooth when freshly deposited, but later becoming roughened and darker.

The caterpillar (Fig. 4, *a, d, e*) is about a half to three fifths of an inch long, when full-grown, and varies from whitish to pinkish in general color. The surface is sprinkled with short whitish hairs rising from minute but prominent tubercles.

The pupa (Fig. 4, *b*) is cylindrical, tapering posteriorly, with a cluster of small hooklets at the tip of the abdomen. It is reddish brown above, the head and thorax the darkest, and much lighter below, approaching a yellowish tint on the wing-pads and abdomen. The tip of the last segment is considerably darker than the rest of the body. The cocoon (Fig. 5) varies in length from two fifths of an inch to half an inch, and is about a fourth of an inch in width. It is composed of delicate silk, often intermingled with

Fig. 3. Mass of flour held together by larval webbing of Mediterranean Flour-moth, *Ephestia kuehniella.*

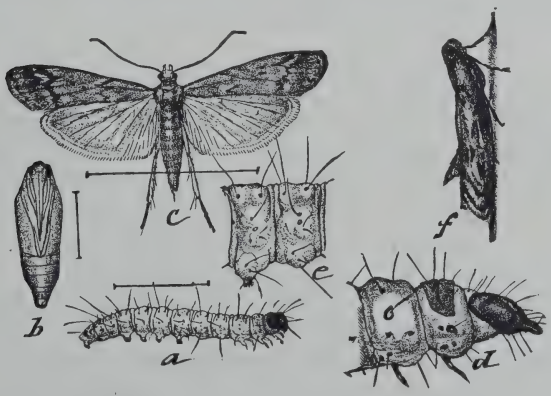

Fig. 4. Mediterranean Flour-moth, *Ephestia kuehniella: a,* larva; *b,* pupa; *c,* adult; *d,* fore part of larva; *e,* middle segments of larva; *f,* adult in resting position. Enlarged as indicated. (U. S. Dept. of Agriculture.)

particles of meal, flour, dirt, or other material. The pupa yields the adult in about two weeks.

Fig. 5. Mediterranean Flour-moth, *Ephestia kuehniella: a,* cocoon from attached side, showing pupa thru thin silk wall; *b,* outer side of same.

The adult moth (Fig. 4, *c, f*) is about half an inch in length, and about seven eighths of an inch from tip to tip across the expanded wings. The front wings are medium gray, sprinkled with blackish scales and specks, and with a V- or W-shaped black line crossing about a third of the distance from the base. The hind wings are silvery whitish, with a darker border. Both pairs of wings are heavily fringed.

LIFE HISTORY, HABITS, AND INJURIES

This insect breeds thruout the year when the temperature permits. The female may deposit as many as two hundred eggs, which are placed singly in flour, in cracks of the floor, and in various places about the machinery of the mill. These eggs hatch in a little more than a week, on an average, the period being of course lengthened if the weather is cool. The caterpillars may get their growth in about forty days, and the pupa yields the adult in about eleven days. Approximately eight weeks are thus necessary to the development of a generation, with a variation of a week or more in one direction or the other according to the temperature. The adults live a little over a week. They have been known to fly at least six or seven rods from the place of emergence. They are active at night, but are not attracted to lights.

Altho wheat flour is most commonly infested, the larvæ of this moth are found also in rice flour, buckwheat flour, crackers,

cotton-seed, corn-meal, oatmeal, rolled wheat, and other prepared cereals. They sometimes live, it is said, in the nests of bumble-bees, and in the hives of the honey-bee.

The Mediterranean flour-moth is common and widely distributed on both sides of the world. It was first detected in Illinois in 1894.

The economic importance of this insect is shown by a statement made by Dr. F. H. Chittenden, of the United States Department of Agriculture, in a recent circular of the Bureau of Entomology on this pest (No. 112, issued March 7, 1910), in which he says that 'this flour moth is attracting more attention than any insect that ever infested mills or other buildings where cereals are stored; indeed, it is almost the sole topic of complaint of millers at the present writing, correspondence in regard to weevils and flour beetles, which was at one time heavy, having fallen off very noticeably. * * *

"As to the losses caused directly and indirectly by this insect, it has been difficult," he adds, "to obtain estimates, the lowest being between $100 and $200 to a mill of 1,000 barrels capacity. The average loss due to closing down the mill and cost of treatment seems to be not far from $500 for each fumigation, 'to say nothing of the loss to business,' according to one Kansas milling firm. An estimate of $1,000 for two fumigations can not be far from right." * * * Thus, cleanliness in and about the mill, and care in examining returned bags and other materials entering it, will go far towards preventing or diminishing trouble from this moth.

TREATMENT

Where a mill is already infested, all flour or other mill products containing the insect should be promptly burned, and all spouts, elevator legs, other parts of machinery and other equipment, as also the walls, ceiling, and especially the corners in every part of the building, should be thoroly cleaned. Such thoro cleaning must be followed by fumigation with hydrocyanic acid gas, or by the use of artificial heat, both of which operations are described farther on in this paper under the head of Measures of Prevention and Remedy.

THE INDIAN MEAL MOTH

(Plodia interpunctella Hübn.*)*

With habits somewhat like those of the Mediterranean flour-moth, but occurring usually on the grain itself or else in meal, the caterpillar of this insect does most of its injury by spinning silk over whatever food it chances to be feeding on. It may construct a silken tube to live in, or simply spin its web in every direction. Bags of grain may thus become completely covered with closely matted silk, which it is practically impossible to remove, so that

the grain must be rebagged before shipment. The caterpillar also spins a cocoon in the midst of its food materials.

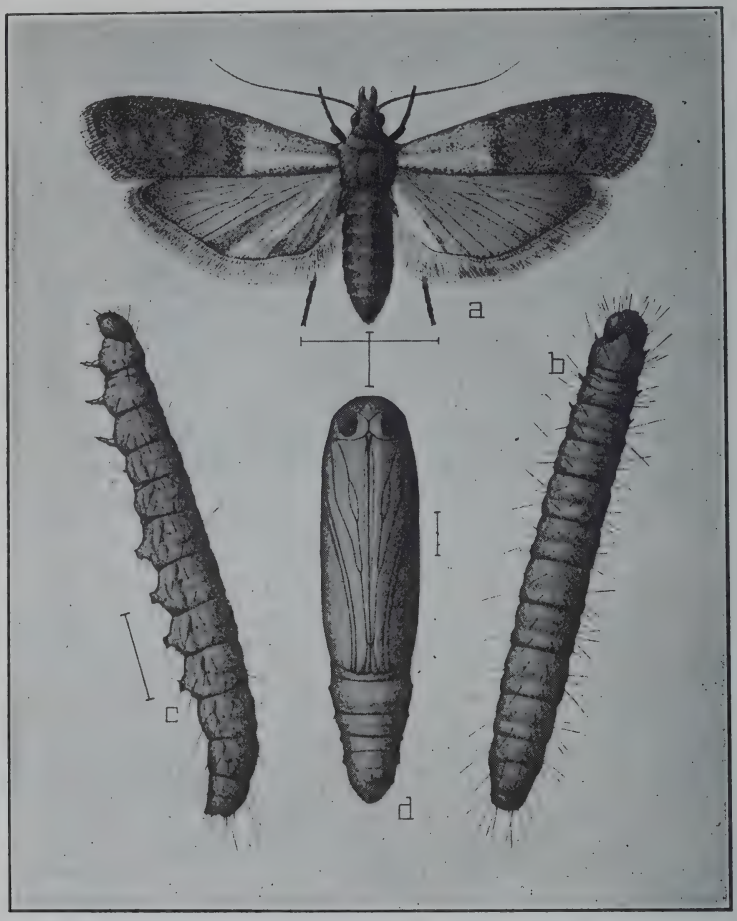

Fig. 6. Indian Meal Moth, *Plodia interpunctella: a,* adult moth; *b,* dorsal view of larva; *c,* side view of larva; *d,* pupa, ventral view. Enlarged as indicated.

The egg of the moth is whitish, and very small. The caterpillar (Fig. 6, *b, c*) is dull olive-greenish, varying to pinkish or whitish, and its elliptical, cylindrical cocoon is olive-green varying to light brown. The moths (Fig. 6, *a*) are active creatures, the outer two thirds of their fore wings reddish brown and the center copper, while the inner or basal third is dirty grayish. They measure about five eighths of an inch across the expanded wings.

The generations of this insect are irregular, and vary in number according to the temperature. The female may lay as many as

(The text of this intercalated page should immediately precede the heading Granary Beetles and Weevils, on page 77.)

THE MEAL SNOUT-MOTH

(*Pyralis farinalis* Linn.)

Hidden away in whatever substance is infested by it, the caterpillar of this beautiful moth is seldom seen. Its habits are somewhat similar to those of the Mediterranean flour-moth in that it lives within a silken tube, but it is more indiscriminate in its food. Thus it may feed upon the chaff from shelled corn in preference to the corn itself. Its silken tube is finely made, and completely covered by attached particles of the food.

The adult, or moth, of this species is really a very beautiful insect. Its wings are delicately colored, the base and outer portions of the front wings are brownish, and the whole of the middle portion is dusky whitish. Two wavy whitish lines cross these wings separating the light middle section from the brownish basal and apical parts. The hind wings are dusky whitish, with two wavy whitish lines running thru them and with a few brownish spots of varying size near the hind margin. The eggs are laid in masses and are irregular in shape. The caterpillar is dirty grayish in appearance, darker at both ends, the head brownish red. The pupa is brownish red and is enveloped by a cocoon.

The life history of this insect is not well known, but there are probably at least four or five generations in a season. Under ordinary conditions a generation has been known to develop in eight weeks in spring, and a shorter period may be expected at higher temperatures.

Altho a general feeder, this insect seems nevertheless to prefer waste matter, in damp places—accumulations of straw, chaff, meal, or other waste products from the granary or mill, occurring in corners, outhouses, and the like. It has also been reported to feed on hay, straw, corn, clover, seeds, dried plants, the grains and their products, and vegetable garbage.

Again, thoro cleanliness in regard to accumulations of rubbish in corners and so on, is prophylactic against this insect, and usually all that is required when the premises become infested is cleaning up and burning the infested material. If this is not possible, one should fumigate with carbon bisulfid, or use artificial heat.

three hundred and fifty eggs, either one by one or in clusters of a dozen or more. These eggs may hatch in four days, under favorable temperature conditions, and a generation may mature in about five weeks.

The food of this species is not limited to grain, flour, or meal, but includes such materials as preserved and dried fruits, peas, beans, edible nut-meats, chocolate beans, spices, sugars, yeast cakes, and some kinds of dried roots and barks. When infesting grains, this caterpillar eats out the embryo, leaving the rest of the kernel. A single larva will destroy a dozen or more grains, according to its size, and when thus engaged it spins its silk over everything in its immediate vicinity.

The species is found everywhere in the United States.

Fumigation with carbon bisulfid or with hydrocyanic acid gas, or the use of artificial heat, are the standard measures for the destruction of this as of most other insect pests of the granary and the mill.

GRANARY BEETLES AND WEEVILS

The hard-bodied insects known as beetles and weevils differ from granary moths in having biting jaws and horny wing-covers inclosing the membranous lower wings. They pass thru the same stages of development as the moths, but in the young, active stage, tho similar to caterpillars, they may be commonly distinguished by the absence of abdominal legs. In the third, or pupal, stage, they are not protected by a cocoon, and are usually white, with the appendages free. Unlike the moths, the adult beetles and their larvæ usually occur together, feeding on the same substances.

THE CONFUSED FLOUR-BEETLE

(Tribolium confusum Duv.*)*

Any small, shining, reddish brown beetle, about an eighth of an inch long, crawling about in large numbers in flour, meal, or prepared cereals, is almost certainly this insect. It is a flattened, oval beetle with the head and upper parts of the thorax densely covered with minute punctures, and with the wing-covers ridged lengthwise and sparsely punctured between the ridges. Its very minute eggs are white. The wormlike larvæ are cylindrical, wiry, white tinged with yellowish, and about three sixteenths of an inch long. The pupa is white.

Altho this insect is extremely common, living on almost any kind of vegetable debris, its life history is imperfectly known. Its eggs are said to hatch within six days at most favorable temperatures, and the larvæ to reach their growth in twenty-four days

and the pupa in six—making a period of about five weeks for the development of a generation from the egg. Four or five generations may occur in a year, on an average, the number being de-

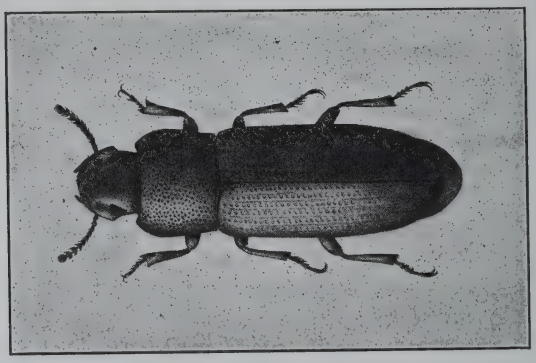

Fig. 7. Confused Flour-beetle, *Tribolium confusum*, adult. ×24.

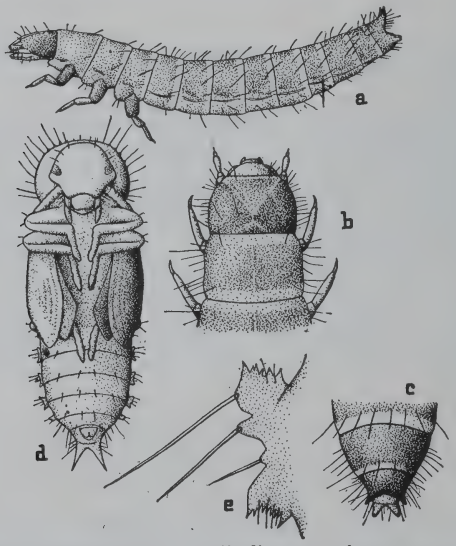

Fig. 8. Confused Flour-beetle, *Tribolium confusum: a*, larva (×24); *b*, head of larva, greatly enlarged (dorsal view); *c*, anal end of larva, greatly enlarged (dorsal view); *d*, pupa (×24); *e*, lateral appendage, greatly enlarged.

pendent, however, upon the temperature, since development continues as long as this is favorable. This beetle is commonly found in oatmeal, corn-meal, prepared wheat and flour, seeming to have a preference for these breakfast foods. It is by no means limited to such materials, however, but has been reported from such substances as ginger, peanuts, beans, peas, orris roots, cayenne pepper,

baking-powder, and snuff. Corn and wheat are also often infested by it, beetles and larvæ feeding upon the grains together, the former, in fact, being perhaps more destructive, and certainly more active, than the larvæ.

This species occurs all over the United States, and is cosmopolitan in its range.

Another beetle, called the rust-red flour-beetle (*Tribolium ferrugineum* Fabr.), less common than the preceding, is often found with it, being similar to it both in habits and in appearance. It is specifically different in the shape of the head and the terminal joints of the antennæ. It is also more southern in its distribution.

These insects may be killed in the grain by the use of heat, or by fumigation with insecticide vapors, as is elsewhere described; and all valueless infested material should be gathered up and burned.

THE SAW-TOOTHED GRAIN-BEETLE

(*Silvanus surinamensis* Linn.)

A minute, flattened, chocolate-brown beetle, with the margins of its thorax roughened with toothlike projections, if found abundant in groceries or other edible substances, may be assumed to be this grain-beetle. The slender adult is not more than a tenth of an inch long. The thorax is marked with two longitudinal

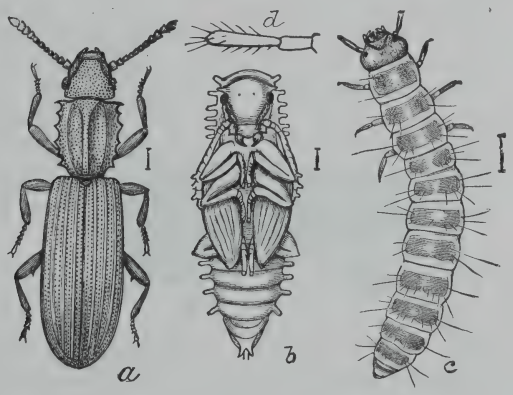

Fig. 9. Saw-toothed Grain-beetle, *Silvanus surinamensis: a*, adult; *b*, pupa, under side; *c*, larva. Enlarged as indicated. (U. S. Dept. of Agriculture.)

grooves, one on each side, and with six minute teeth, like those of a saw, on each lateral edge. The head and thorax are densely covered with fine punctures, and the wing-covers are finely punctured and lined. The larva is somewhat flattened, with transverse, rectangular, yellowish spots above, margined with the white of the

general body-color. On the thorax and anterior abdominal segments, a white line divides the rectangles into squares. The pupa is white, and is occasionally inclosed within a delicate cocoon composed largely of particles of the food substance. From five to seven generations of this species may be developed within a single year, the number depending, as usual, upon the temperature and upon the supply of food. The beetles infest almost anything of a vegetable nature used as human food, including preserved fruits and various cereals, bread, nuts, seeds, red pepper, yeast, spices, sugar, flour, and also tobacco and snuff.

This beetle is widely distributed, and virtually cosmopolitan in its range. At the Columbian Exposition in 1893 it was found in exhibits of food products from Brazil, Argentina, Paraguay, Trinidad, Mexico, Greece, Italy, Tunis, Liberia, and Java. It is generally distributed in North America.

THE GRANARY WEEVIL

(Calandra granaria Linn.*)*

Corn or wheat, the kernels of which contain a small, fat, legless, whitish grub, somewhat like those commonly found in nuts, but of much smaller size, is infested either with this insect or the closely related rice-weevil, next discussed. The beetle (Fig. 10) is about an eighth of an inch long, ovate, convex, and uniformly chestnut-brown, the thorax with elongate punctures in more or less definite lengthwise rows, and the wing-covers finely grooved and ridged lengthwise. The head is prolonged into a stout probos-

Fig. 10. Granary Weevil, *Calandra granaria,* adult. × 25.

cis-like snout bearing the elbowed antennæ attached to its sides. The minute white egg is placed in a cavity made in a kernel of wheat or corn for the purpose. There is usually but a single grub to a grain of wheat, but there may be as many as two or three in a kernel of corn. As the beetles are unable to fly, they do not infest the ripened grain in the field. There may be four or five, or even more, successive generations in a year, each requiring about forty days for its development. As the adults

may live six months or more if abundantly supplied with food, several generations commonly coexist in badly infested grain. Such grain is unfit for human consumption, and as it can not be separated from that which is uninjured, it is often a total loss.

Treatment by heat, and fumigation with carbon bisulfid, are the standard methods of destruction.

The species is widely distributed in the United States, but is more common southward.

THE RICE-WEEVIL

(*Calandra oryza* Linn.)

The beetle of this species (Fig. 11) differs from the granary weevil in being slightly smaller and of a duller brown, and by having on the wing-covers four more or less distinct reddish spots, two at the front angles and two near the tips. It is, moreover, able to fly. It varies in color, from light brown to black, and its thorax

Fig. 11. The Rice-weevil, *Calandra oryza,* adult. × 25.

is densely covered with minute circular punctures not arranged in longitudinal lines. In its early stages it is so similar to the preceding species that a careful technical description is necessary to separate them.

This beetle, having the power of flight, may infest the grain in the field even before this is fully ripe. A single female may produce as many as four hundred eggs, and altho the sexes frequently pair, reproduction sometimes occurs without this preliminary. The grub hatching from the egg is creamy white with a brownish head. The pupa is at first white, but turns to brownish as the beetle develops within. It is formed in a definite cavity or cell within an infested grain. Development may be greatly retarded, or even arrested, by cold weather, the insect living on in whatever stage it may have reached. A generation may develop in three to six weeks, according to temperature. The larvæ may reach full size in about sixteen days.

This weevil is especially troublesome southward, where it infests corn in the field and afterwards in the crib. The beetles begin

to deposit their eggs in the South, early in June, and continue until the corn is ripe, adults emerging in about a month after the eggs are placed. This weevil may infest most of the cereals, and is especially common in rice. It has also been found in tobacco, in boxes of crackers and cakes, in macaroni, and other bread stuffs, and in barrels of flour and bags of meal. Its effect on ears of corn infested by it resembles closely that of the Angoumois grain moth, and as many as three or four may live and mature in a single kernel of that plant.

THE YELLOW MEAL-WORM

(*Tenebrio molitor* Linn.)

This is a cylindrical, yellowish, shining grub (Fig. 10, 11) about an inch long when full-grown, with the general appearance of a thick wireworm, often found in stored flour, meal, bran, and other similar material The adult belongs to the family known as

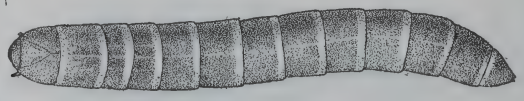

Fig. 10. Yellow Meal-worm, *Tenebrio molitor,* larva, seen from above.

darkling beetles (*Tenebrionidæ*), because they avoid the light. They do not infest crops, and are economically important only as they occur in stored products intended for consumption by man or beast. The beetle of this species (Fig. 12) is about five eighths of an inch long, somewhat flattened, with head and thorax minutely punctured, and with longitudinal raised lines on the wing-covers. The eggs are deposited singly or in small clusters in the food sub-

Fig. 11. Yellow Meal-worm, *Tenebrio molitor,* larva, side view.

stance of the grubs. They may hatch in about two weeks. The young grub is white at first, but gradually turns to yellowish, darker at each end and also at the end of each segment. It may complete its growth in about three months. There is but a single generation in a year, the beetles emerging in April, May, and June. They are nocturnal in habit, flying about at night. The grubs commonly get their growth by fall or early winter, remain more or less active

during the winter season, and pupate in early spring, to emerge several weeks later in the beetle stage. The meal-worm feeds on

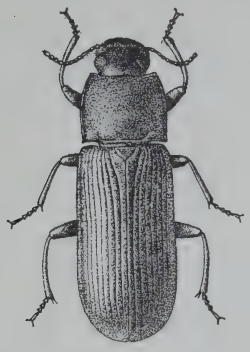

Fig. 12. Yellow Meal-worm, *Tenebrio molitor*, adult.

flour, meal, and even the dust and refuse of mills and granaries. It has sometimes been found in ship's biscuit, and will doubtless infest similar cooked foods exposed to its invasion.

A closely related species known as the dark meal-worm *(Tenebrio obscurus* Linn.*)* is extremely similar to the foregoing, but dull pitchy black. In habits and economic relations this is a close parallel to the preceding, altho the larva has been taken in more unusual substances, such as cotton-seed, commercial soda, cotton-seed meal, black pepper, and commercial fertilizer. Both these species avoid the light, and are most likely to breed in dark unclean corners of mills and elevators. Thoro cleanliness is, consequently, an important preventive.

MEASURES OF PREVENTION AND REMEDY

Insects of the granary are much more easily kept out than put out. All places where grain or any of its products are stored should above all things be kept clean—not merely apparently clean, but actually so. Cracks in the walls and floor, for example, may seem to be clean when swept over, but may really be filled with the dust of grain and similar debris and thus become a breeding place for a number of granary insects. Storage rooms and bins should, in fact, be so constructed as to be free from cracks, the walls, floor, and ceiling smooth, and everything solid and snug. No rubbish of any kind should be allowed to accumulate, either in the building or on adjacent premises. Everything should also be done to keep insects out of the storehouse. Grain should be brought in from the field as soon as possible, since the longer it is exposed after ripening the more likely is to become infested by the Angoumois grain moth, the rice-weevil, and some other species. If found in-

fested when brought in from the field, it should at once be fumigated with carbon bisulfid in a room especially constructed for the purpose in a manner to be described later. In the management of mills, returned bagging, second-hand machinery, and the like, should be carefully inspected or, better, regularly fumigated.

The more important special measures which, used alone or in combination, may prevent infestation by granary pests, may be described as follows.

1. Small grain should be threshed and stored as soon after ripening as possible. Wheat should be harvested and threshed directly from the shock if practicable, but if stacked, should not stand in the field longer than is absolutely necessary.

2. The place intended for the reception of a crop should be thoroly cleaned out some time in advance, and if there is reason to suppose that it has contained granary pests, it should be fumigated with sulphur. Complete protection against weevils requires that rooms for grain should be made tight, with windows screened and doors close-fitting, and also that they should be cool and dry. With proper care and some additional expense, any such structure can be made gas-tight and suitable for the fumigation of its contents with carbon bisulfid, but the need of thoro ventilation should not be left out of account.

3. If it were possible to dry grain from the field artificially at a temperature of 125° F. for four or five hours, all insects would be killed and the grain could then be stored in a thoroly clean and tight place, and safely left until needed for shipment or use. Corn which has been shelled dry and sacked is much safer than that left on the ear, whether with or without the husks. Grain stored for seed should be dried artificially, since it not only keeps better and germinates more generally, but it is also less liable to be eaten by such insects as devour the kernel.

4. Farmers, seedsmen, and millers should, in buying grain, make sure that it is free from insects.

Treatment of Infested Grain

When a mill or storeroom full of grain has become infested with granary insects, an inspection should first be made as to the nature and extent of the infestation. Much time and money may often be saved in this way, for the trouble may prove to be of slight practical importance, and capable of being remedied by some simple and inexpensive operation. A seed-corn warehouse, for example, may be so generally infested by several insects that it would seem that serious damage must have been done, but it may be found that the more abundant of these insects are feeding on dust and rubbish derived from the grain, and that only one of them is actually injuring the kernels; and a thoro examination of fair

samples may show that less than one percent of the kernels are actually injured. Corn in the ear may sometimes be sorted to advantage, if infested, with a view to removing ears showing injury and shelling and bagging the remainder. A general infestation may often be checked in its development by opening the warehouse in winter to lower the temperature, or by the use of heat as is presently to be described.

If, however, it appears that an infestation is general and the injury considerable, and that simple measures will not be sufficient, some more general program will be necessary. If fumigation with either carbon bisulfid or hydrocyanic acid gas is practicable under the conditions, this is by all means the most effective and satisfactory process in such cases; but this requires that it shall be possible to make the granary or storeroom virtually gas-tight, or so tight that the leakage of gas will be so slow that a fatal atmosphere may be maintained for a period of several hours.

Hydrocyanic acid gas is the more poisonous of these two substances, but the more difficult and dangerous of application, and as it has comparatively little penetrating power, it can not be used against insects infesting grain in bulk or against those which are inclosed within the kernel. It is the best fumigant, however, for use against the Mediterranean flour-moth, and for any other soft-bodied insects which do not penetrate deeply into the grain. Carbon bisulfid must be chosen if hydrocyanic acid gas is not available. Even where the storage rooms can not be made fit for the fumigation process, it may be possible to accomplish the purpose by constructing a special room or even erecting a small separate building thru which infested material may be passed in comparatively small lots.

Next to fumigation, extremes of temperature, especially sudden changes from one extreme to another, are on the whole, the most effective.

FUMIGATION WITH HYDROCYANIC ACID GAS

Preliminary to the fumigation of a mill, warehouse, or granary, the room or rooms to be fumigated should be thoroly cleaned and the sweepings burned. This operation is particularly important, as the gas to be used has little penetrating power, and living insects nesting away in a pile of rubbish, or hidden in a crevice packed with dirt, may escape uninjured. Next, everything must be done to make the place tight, windows and doors receiving special attention. Cracks around window-frames should be tightly stuffed with cotton batting, macerated paper, or white waste, or else thick soft paper should be fastened over the cracks with carpenters' glue or a good quality of flour paste. Broken or missing window-panes should, of course, be replaced. Keyholes in doors, and spaces between the door-frame and the door itself should be

similarly closed. All outlets to the room—ventilators, registers, pipe openings, and the like, as well as cracks in the floors, ceilings, and walls—should be stuffed with waste and covered with paper. As carpenters' glue is difficult to remove, a good flour paste may be substituted for it where this is a matter of importance.

Hydrocyanic acid gas is produced by the reaction of cyanide of potassium, sulphuric acid, and water, the gas coming off with a more or less violent bubbling of the mingled fluids. The gas evolved is one of the most prompt and powerful poisons in common use, and the residue left after the reaction is sufficiently poisonous to make it necessary that it should be carefully disposed of by burying. The cyanide used should be in lumps, and 98 percent pure. To insure this strength a reliable brand should be bought in its original sealed package. That manufactured by Merck & Company, of New York, is of standard quality and can be depended on. Commercial sulphuric acid is of sufficient purity, but it should have a specific gravity of about 1.83 (66° Beaumé). Cyanide should be protected from moisture and kept in sealed vessels, as it is otherwise liable to decompose. Gloves should be worn while handling either of these chemicals.

To determine the amount of the ingredients needed for fumigation, one must first find the cubic contents of the containing room, making no allowances for furniture or other objects in it. An ounce, by weight, of cyanide, and a fluid ounce of commercial acid are needed for every hundred cubic feet of space in the room.

Three-gallon earthenware jars make suitable generators, and these should be provided at the rate of one for every five thousand cubic feet of space to be fumigated. As, for the best effect, the gas must be held at least eighteen hours, the importance of tight construction is manifest. If, however, this is impracticable, the strength of the gas—the amount, that is, of the ingredients per hundred cubic feet—must be increased according to the judgment of the operator. In some cases even twice the above quantities may be found necessary to a successful operation.

The containers should then be distributed thruout the room or rooms and the proper amount of water should be poured into each. The sulphuric acid should next be measured out and gently poured into the water. The cyanide of potash should be prepared for use by breaking it into lumps somewhat smaller than an egg. This should be done in the open air. It should then be carefully weighed out and placed in thin paper bags in quantity sufficient for each of the containers. One of these should be placed by the side of each jar, and then the sacks should be dropped carefully in quick succession into their corresponding jars in such an order that the operator shall not be exposed to the evolving vapors. When all is done the exit should be closed and locked, and a conspicuous label should be placed outside as a warning.

Fumigation should be done on a quiet day, as a high wind tends to blow the vapor thru such openings as may remain in the walls. A temperature of not less than 70° is to be preferred. Commonly two successive treatments three or four weeks apart are necessary to complete success.

The operator must bear in mind, in his plans and procedure, that everything must be done in such a way that he shall not breathe the escaping gas. Milk, meats, and other moist or liquid food materials, should be removed before fumigating, as they are liable to become poisoned by absorption of the gas. Arrangements should be made to open the building from without for ventilation when the fumigation is completed, and it should not be entered until it is practically free from the gas.

FUMIGATION WITH CARBON BISULFID

This volatile and exceedingly ill-smelling chemical has been more or less used against stored grain insects for many years, but recent experiments, including some of those upon which this discussion is based, have shown that the strengths at which it must be used and the best methods of its application, were but little understood, and that it has often been recommended for too many purposes and for use under really impossible conditions. This has resulted in many failures which have discredited it more or less as an insecticide for granary and warehouse use.

The commercial bisulfid is a heavy, oily fluid with a specific gravity of 1.29, boiling at 115° F., and igniting at about 300° F. It is cold to the touch, and because of its rapid evaporation it produces a freezing sensation when applied to the skin. When handled in quantity one's feet are likely to become cold, especially if any of the fluid is spilled upon the shoes. The vapor is a little over two and a half times heavier than air, a point to be remembered in application, since it goes first to the bottom of the inclosure. When mixed with air it becomes inflammable and explosive, especially when the mixture is in the ratio of about one part of the vapor to fourteen parts of air, equivalent to fifteen pounds of the fluid to a thousand cubic feet of space. Such a mixture of air and bisulfid vapor may be exploded by so small a cause as the spark made by hitting a nail or by turning an electric light on or off, instances of both of which have come within our own experience. The chemical leaves, on evaporation, a residue of impurities which stain cloth and other substances, so that direct contact with it should be avoided. Its rate of evaporation is in proportion to the temperature and the area of its surface of exposure, being very rapid when exposed in shallow vessels and at a high temperature. Its efficiency is also the greater the more rapid the evaporation and the higher the temperature. One volume of the

liquid will produce about three hundred and seventy-five volumes of the vapor.

There is one effect of this gas upon the person handling it which should be especially borne in mind. When evaporated by spraying or sprinkling, or by exposing in many wide and shallow dishes, it accumulates very rapidly in the air, and unless one is careful it will soon affect him dangerously. Operators in large storage rooms applying the fumigant by means of a spray have become unconsciously intoxicated by it, and are liable to be overcome, with dangerous or even fatal consequences. The sense of smell becomes benumbed, hearing and sight are dulled, the action of the heart becomes quick and violent, and the mouth dry and parched. If these symptoms appear, the operator should at once abandon his task. A serious intoxication may last for several hours, accompanied by headache and followed by a taste of the bisulfid in the mouth for a day or two.

Altho carbon bisulfid was formerly supposed to be available only for grain in bulk, and not permissible for flour, it is now known that it may be used in mills without fear of injuring the flour in any way. The method of its use will vary somewhat according to the conditions present, but the fluid should be evaporated as rapidly as possible, and the vapor should be given off from as high a place as possible within the inclosure. A moderately high temperature is to be preferred, but is not indispensable. The best method of distributing the fluid is by means of an atomizer or a spray pump. If the latter is used, the liquid may be sprayed directly upon the ceiling; or it may be simply sprinkled over the exposed surface from a watering-pot.

When these methods are impracticable, it will accomplish the purpose if it is placed high up towards the ceiling in large, very shallow, dishes or pans, the sides not more than a quarter of an inch in height. Bags of cotton-seed or grain may be treated separately by means of an iron tube, provided with a conical tip, and pierced along its sides with holes to permit the escape of the liquid and vapor. In most cases, however, this individual treatment will be found unnecessary.

Our recent experiments, carried on with great care and duplicated many times, have convinced us that an effective fumigation requires ten pounds of carbon bisulfid to every thousand cubic feet of space to be treated. At this strength we have found the fumigant effective against all granary pests and at all temperatures. An effective treatment presupposes a construction of the granary or bin such as to hold the vapor for several hours without serious loss by leakage. It is at this point that most persons fail in practical work, since few storehouses or granaries are sufficiently tight to hold the vapor long enough, without special and careful preparation.

To protect one's grain or other property against insect pests he must either build his granary or storerooms in such a way as to permit effective fumigation, or he must provide a properly built room to be used especially for fumigation of infested materials. This room may, of course, be of any convenient shape, but it should not have more windows or doors than necessary, and it should not contain more than fifteen thousand cubic feet of space. The walls, ceiling, and floor should be similarly constructed—built, that is, of two layers of seasoned, grooved flooring of good quality, the outer layer running at right angles to the inner, and with glazed building paper between the two. Care must be taken with this layer of paper, as it is an important part of the structure. Wherever the edges are joined they should be broadly overlapped and secured by gluing. The door should be similarly constructed. The interior of the building should have all cracks, crevices, and holes closed by putty, after which it should receive a heavy coat of paint and should then be lined thruout with linen cloth stretched tight, lapped at the edges, and held in place by lathing. This cloth should be so placed that the laps do not come at the corners of the room, and it should be finally coated with moderately thick carpenters' glue, which substance has the great advantage that it is insoluble in carbon bisulfid. It must, however, be renewed if it cracks and scales off, as is sometimes the case, especially when the lumber is not well seasoned. The door should be treated like the walls. It should fit as tightly as possible, and clamps similar to those on refrigerator doors should be used to batten it.

THE USE OF COLD AND HEAT

It is a well-known fact that insects are peculiarly sensitive to sudden and extreme changes in temperature, and under storage conditions this susceptibility can often be made use of to excellent advantage. A zero temperature following upon one of 50° or 60° F., and quickly followed again by a temperature of 100° or more, will commonly kill every insect in an infested mill or storage room. Where steam heat can be applied, especially in northern Illinois, granary pests can thus be readily exterminated. Indeed, a temperature of 125° to 130° F. maintained for several hours by artificial means will itself destroy most insects; but for this it is necessary to provide steam radiators near the floor, to use direct steam under pressure, and to close down the mill or other building for about twenty-four hours.

CONTACT INSECTICIDES

In cleaning up infested places, cracks in the floor, walls, and ceiling must often be treated in a way to destroy the insects con-

cealed within them. Gasoline and benzine are both excellent for this purpose, provided fire and lights be kept away from them until they have evaporated, as of course they presently do. They may be applied in any convenient way—by brushing, sprinkling, or spraying, according to the conditions present. They act at once upon contact, and if doors and windows are opened immediately after the application the vapors will soon disappear.

A KEY FOR THE IDENTIFICATION OF GRANARY INSECTS

This table is introduced to enable practical grain men and millers to identify insects found injuring stored grains and their products. It is simply a working table for the most important of these insects, and does not include, of course, all insects to be found in stored grain or in mills, some of which may be merely feeding on debris. The table is as free from technicalities as it is possible to make it. It should be remembered that all of these insects have four distinct stages of development, proceeding in succession from the egg to larva, pupa, and adult; also that all adult insects have six legs, neither more nor less, and that all here considered have two pairs of wings.

A. Moths or millers: the larva a caterpillar with distinct head, three pairs of thoracic legs and five pairs of abdominal legs, one of these pairs on the last segment. The larva usually spins a cocoon; the pupa is brownish, its appendages not free. The adult insects have two pairs of wings, the front pair longer and usually more colored than the lower or hind pair, which are usually grayish. Their bodies are soft, pliable, and covered with microscopic scales, like dust, and fine hairs. Insects of medium size, usually about half an inch long.

a. A small whitish caterpillar, living in grains of corn or wheat, eating out the embryo and other soft portions, pupating within the grain, and emerging thru a round hole at or near the tip of the kernel; this hole is covered with silk. Badly infested ears of corn look as if riddled with shot. Adult moths grayish clay-yellow, small..... .....*The Angoumois Grain Moth.*

aa. Caterpillars which spin much silk, usually forming a silken tube to which they retire; this tube covered with particles of whatever substance they happen to be feeding upon. Living in flour, meal, or chaff, sometimes among grain, or in food substances such as prepared cereals. The full-grown caterpillars make a cocoon.

b. A free-living caterpillar, usually not concealed within a silken tube, olive-green to pinkish in color, infesting grain or meal, webbing particles together, covering bags

of grain with a web of silk, and generally scattering silk in all directions. The moth has the outer two-thirds of the fore wing reddish brown with the luster of copper, while the inner or basal third is soiled grayish; its hind wings are grayish. The cocoon is elliptical, slender, fragile, and of clear silk.....*The Indian Meal Moth.*

bb. Caterpillars living in densely woven silken cases which are covered with particles of the food substance. Common in flour or chaff in corners.

c. A yellowish white to pinkish caterpillar living in flour, webbing it together and forming a cocoon covered with particles of flour. The moth is dark grayish, the fore wings silvery gray mottled with blackish streaks, one of which, obscurely resembling a letter V or W, crosses the wing between its base and middle; the hind wings are silvery whitish.....*The Mediterranean Flour-moth.*

cc. A soiled grayish caterpillar, darker at each end, living in chaff or other vegetable debris in dark damp places, securely webbing the food substance together so that it becomes matted; larval case and cocoon completely hidden, covered with the food substance. Adults very beautiful, base and outer portions of the front wings brownish red, the middle portion whitish, margined on each side by a thin wavy whitish line which crosses the wing and separates the three color divisions. The hind wings are whitish, with a whitish wavy line running thru them and a row of black spots around the hind margin.....
.....*The Meal Snout-moth.*

AA. Beetles or weevils; the larva or grub with a distinct head, usually three pairs of thoracic legs but no abdominal legs, biting jaws. Does not spin a cocoon. The pupa is whitish, the appendages free. The adults are hard and horny, with two pairs of wings, the upper pair horny, closed together in a straight line over the back, and concealing the larger, folded, thin under pair. Their mouths are constructed for chewing; placed in weevils at the tip of a snoutlike prolongation of the head. Insects differing much in size; usually about as large as a grain of wheat, but varying up to a half-inch or more in length.

d. Small insects living in kernels of grain, or among grain and other stored products.

e. A very small, fat, humped-up grub, occurring in kernels of wheat or corn, like the grub in chestnuts but smaller, yellowish white, legless, very hump-backed and wrinkled, unable to crawl, its head inconspicuous and yellowish

brown. The pupa is found within the kernel. The adult is smaller than a grain of wheat, with a snoutlike prolongation of the head, and elbowed feelers attached to the snout. Two brownish species, which feign death when disturbed. In ears of corn their work is very similar to that of the Angoumois grain moth, previously described.

f. The adult beetle is chestnut-brown, without spots on its upper wings. A slightly larger weevil than the next, more common in the North.....
.....*The Granary or Black Weevil.*

ff. The adult beetle is somewhat duller brown than the preceding with four reddish spots, one on each outer corner of the upper wing. A southern species.....
.....*The Rice or Spotted Weevil.*

ee. Small, more or less slender, somewhat flattened grubs, with distinct head and thoracic legs, crawling about in the debris of various grains or their products, or in vegetable foodstuffs. The adults are flattened, longer than wide, the head not prolonged into a snout. They occur with the grubs, actively feeding. Two distinct species and their allies; all small.

g. The grub uniform in color, whitish, about a quarter of an inch long, slender, its head narrower than the first body segment; pupa with the thorax not toothed laterally, but with most of the abdominal segments bearing a toothlike lobe, acute at each outer corner and toothed along its sides. The adult beetle is active, smooth, elliptical, and reddish brown. *The Confused Flour-beetle.*

gg. The grub whitish, with a rectangular yellowish area on each segment above, only the margin whitish as seen from above; the head broader than the first body segment. The pupa bears along each side of the thorax and abdomen a series of stout lobelike teeth, which are cylindrical-rectangular and blunt. The adult beetle is smaller than in the preceding species, color dark chocolate-brown, the sides of the thorax toothed like a saw..
.....*The Saw-toothed Grain-beetle.*

dd. Large insects, living concealed in the bottoms of bins, corners, and the like, feeding upon flour, meal, or bran. The adults are large black beetles; the larvæ, large, cylindrical, wormlike creatures, resembling wireworms.

h. The adult not quite black in color, shining, its third antennal joint not quite twice as long as the second; larva light yellowish, shining....*The Yellow Meal-worm beetle.*

hh. The adult black and without luster, its third antennal joint thrice as long as the second; larva very dark, shining.
.....*The Dark Meal-worm beetle.*